DOI: 10.1007/s11676-007-0059-z

Storage of biomass and net primary productivity in desert shrubland of *Artemisia ordosica* on Ordos Plateau of Inner Mongolia, China

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Abstract: Biomass and net primary productivity (NPP) are two important parameters in determining ecosystem carbon pool and carbon sequestration. The biomass storage and NPP in desert shrubland of *Artemisia ordosica* on Ordos Plateau were investigated with method of harvesting standard size shrub in the growing season (June−October) of 2006. Results indicated that above- and belowground biomass of the same size shrubs showed no significant variation in the growing season (p>0.1), but annual biomass varied significantly (p<0.01). In the *A. ordosica* community, shrub biomass storage was 699.76−1246.40 $g \cdot m^{-2}$ and annual aboveground NPP was 224.09 $g \cdot m^{-2} \cdot a^{-1}$. Moreover, shrub biomass and NPP were closely related with shrub dimensions (cover and height) and could be well predicted by shrub volume using power regression.

Keywords: Shrub biomass, Net primary productivity, *Artemisia ordosica* community, Ordos Plateau, Inner Mongolia

Introduction

Ordos Plateau is situated in the southern part of Inner Mongolia, Northern China and at the transition between semiarid and arid ecosystems (Li 1990). In the past, this area was known for its fine pastures with ample water and abundant grass (Vermeer 1998; Zheng *et al*. 2005). However, the grasslands are now severely degraded because of serious desertification and the landscape is characterized by desert shrub vegetation (Zhang 1994). The conversion of grasslands into desert shrub systems has greatly influenced ecosystem function and biogeochemistry cycles (Chen *et al*. 2002; Cheng *et al*. 2007; Jin *et al*. 2007). Biomass storage and net primary productivity (NPP), as two important indexes in measuring ecosystem function, would also be substantially altered by the vegetation conversion (Huenneke *et al*. 2002; Cheng *et al*. 2007). Moreover, biomass and NPP are the key parameters in determining ecosystem carbon pool and carbon sequestration (Geider *et al*. 2001). However, we still lack enough information about biomass accumulation and NPP pattern in desert shrublands in northern China. Therefore, reinforcing research on biomass storage and NPP of such grassland biome is crucial for predicting carbon sink of Chinese terrestrial ecosystems.

On Ordos Plateau, *Artemisia ordosica* is the dominant and the most widespread vegetation cover. In the present study, the shrub community of *A.ordosica* was selected and its biomass storage and annual NPP were investigated during the growing season (June-October) of 2006. The questions addressed were: (1) storage and allocation of biomass; (2) estimation of NPP; (3) relationships of biomass and NPP with shrub size.

Materials and method

Study area description

The study area (39° 29′ N, 110° 11′ E) is situated in the Mu Us sand land on Ordos Plateau of Inner Mongolia, China and in the vicinity of Ordos Sandy Grassland Research Station. The elevation of the sampling site is 1 335 m. The climate is a typical semiarid continental climate with remarkable seasonal and diurnal temperature variation and low rainfall. Annual mean precipitation is 345.2 mm with annual mean evaporation 2 535 mm. The mean precipitation from April to October is 321.8 mm, accounting for about 93% of annual precipitation. Annual mean temperature is 6.7ºC and the monthly mean temperatures are below 5ºC from November to March, and between 7.4 and 21.9 ºC from April to October (Zheng *et al*. 2005).

Field sampling

Before biomass harvesting in the first time, three 10 m×10 m plots were set and shrub height and cover diameter were measured in order to rank the shrub size. According to the shrub size investigated, we divided the shrubs into three classes as large size shrub, middle size shrub and small size shrub (Dong 1996). In each month from June to October in 2006, total 15 different size shrubs (five individuals for each class shrubs) were har-

Foudation project: National Natural Sciences Foundation of China (Nos. 40501072 and 40673067) and the Major State Basic Research Development Program of China (No. 2002CB 412503) and the Knowledge Innovation Program of the Institute of Geographic Sciences and Natural Resources Research,CAS “The effect of human activities on regional environmental quality, the health risk and the environmental remediation”

Received: 2007-10-09; Accepted: 2007-10-28

The online version is available at http://www.springerlink.com

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Responsible editor: Chai Ruihai

vested and shrub heights and cover diameters were measured. After harvesting, new branches developed in the present year were separated from old branches. For determining the below-ground biomass, shrub roots in 0–20 cm soil depth were sampled because our investigation indicated that 85% of roots distributed on this soil layer. All samples were oven-dried at 65℃ to constant weight (0.01 g) in laboratory.

In order to investigate the change of shrub dimensions during the growing season, another three plots (10m×10 m in size) were set in June, August and October in 2006 for measuring shrub height and cover diameter. According to the change of shrub size, the numbers of different size shrubs in the given studying area were determined in the three growing stages.

Estimation of biomass storage

The biomass storage of shrubs was estimated by the following equation.

$$B = \frac{G_L \times N_L + G_M \times N_M + G_S \times N_S}{A} \quad (1)$$

Where B is the shrub biomass storage, g·m^{-2}; G_L, G_M and G_S the biomass of large size, middle size and small size shrubs, respectively, N_L, N_M and N_S the numbers of large size, middle size and small size shrubs in the given plot, respectively, and A is the plot area 100 m^2.

Results

Seasonal dynamics of above- and belowground biomass of single shrubs for different sizes

During the growing season, above- and belowground biomass of single shrubs in the same size showed no significant variation (p>0.1, Table 1), but annual biomass varied significantly (p<0.01, Table 1), which indicated that biomass accumulation was mostly attributed to the growth of new branch. In contrast to typical grassland, shrubland biomass mostly distributed on aboveground and the aboveground biomass occupied about 55%-80 % of the total shrub biomass. Ratios of below- and aboveground biomass (B/A) in the shrubland studied was about 0.25−0.82.

Ecosystem biomass storage and NPP

According to the shrub biomass and the numbers of different size shrubs investigated in the three growing stages, ecosystem storage and allocation of biomass and annual aboveground NPP were estimated by equation (1). In the *A.ordosica* community, shrub biomass storage was 699.76−1246.40 g·m^{-2} and annual aboveground NPP was 224.09 g·m^{-2}·a^{-1} (Table 2). The yearly accumulated biomass occupied 18%−32% of ecosystem biomass storage, which indicated *A. ordosica* vegetated fast in the community.

Relationships of shrub biomass with shrub height and cover diameter

In the present study, shrub biomass was closely related with shrub dimension (height and cover diameter), with r^2 values of 0.563−0.933 (p<0.0001, Table 3). Moreover, shrub biomass and NPP were well predicted by shrub volume (Diameter × Height) using power regression. Therefore, shrub volume can be as a good parameter for the simulation of shrub biomass storage and NPP pattern in desert ecosystems.

Table 1. Biomass allocation of single shrubs for different sizes in *A. ordosica* community on Ordos Plateau of Inner Mongolia during the growing season of 2006

Month	Above-ground biomass (g/each shrub)		
	Large size	Middle size	Small size
June	834.02−1218.40	397.05−588.64	36.21−165.74
July	735.29−1398.24	226.45−575.95	24.33−92.70
August	684.26−1528.27	276.49−498.28	39.27−91.90
September	612.56−1436.99	343.01−506.06	34.49−157.60
October	490.28−2366.34	383.46−737.32	31.13−153.64
Month	**Below-ground biomass (g/each shrub)**		
	Large size	Middle size	Small size
June	293.84−409.50	144.85−229.41	30.98−86.91
July			
August	179.23−381.24	91.81−155.39	18.08−70.17
September			
October	169.82−486.92	141.07−269.50	15.77−85.28
Month	**Annual biomass (g/each shrub)**		
	Large size	Middle size	Small size
June	42.98−168.85	25.48−49.13	7.94−33.42
July	99.61−286.85	59.84−209.05	18.65~47.71
August	185.91−463.89	98.31−220.83	21.98−64.17
September	306.43−694.16	144.99−251.52	23.13−114.37
October	221.73−557.1	131.47−233.40	21.98−80.49

Table 2. Biomass storage and NPP of the *A. ordosica* community on Ordos Plateau of Inner Mongolia, China

Biomass allocation（g·m^{-2}）			Total Biomass storage（g·m^{-2}）	Aboveground NPP (g·m^{-2}·a^{-1})
Annual biomass	Old branch biomass	Root biomass		
77.46−224.09	410.61−858.56	127.55−310.38	699.76−1246.40	224.09

Table 3. Relationships between shrub biomass and shrub dimensions (cover diameter and height)

Parameters	Aboveground biomass		
	F	r^2	Correlations (n=57)
Diameter (D)	620.51	0.919	Y=0.044 + D$^{2.098}$, p<0.0001
Height (H)	669.89	0.924	Y=0.002 + H$^{2.909}$, p<0.0001
Diameter × Height (D×H)	760.04	0.933	Y=0.010 + (D×H)$^{1.234}$, p<0.0001
Parameters	**Belowground biomass**		
	F	r^2	Correlations (n=27)
Diameter (D)	157.11	0.863	Y=0.118 + D$^{1.643}$, p<0.0001
Height (H)	190.34	0.884	Y=0.006 + H$^{2.537}$, p<0.0001
Diameter × Height (D×H)	184.29	0.881	Y=0.033 + (D×H)$^{0.978}$, p<0.0001
Parameters	**Net primary productivity**		
	F	r^2	Correlations (n=57)
Diameter (D)	119.37	0.621	Y=0.132 + D$^{1.546}$, p<0.0001
Height (H)	94.02	0.563	Y=0.021 + H$^{2.009}$, p<0.0001
Diameter × Height (D×H)	111.18	0.604	Y=0.053 + (D×H)$^{0.886}$, p<0.0001

Discussions

The community of *A. ordosica* is one of the most widespread vegetation cover in northwestern China, and Ordos Plateau is the centre area for *A. ordosica* development. In sandy grassland ecosystems in China, the shrub ecosystem of *A. ordosica* is an important component and plays a significant role in combating desertification and promoting the built-up of plants (Li 2001). In recent years, a concerted effort has been made to investigate the plant biological characteristics, species composition, community biodiversity and ecosystem function (Yang *et al*. 1994; Guo *et al*. 2000; Xiao *et al*. 2001; Wang *et al*. 2006; Zhang *et al*. 2007), but information on biomass storage and NPP is still limited. In earlier years, Wang and Li (1994) investigated the annual aboveground biomass in *A. ordosica* communities and found the highest annual aboveground biomass of 310.0 $g \cdot m^{-2}$ appeared in semi-mobile dunes. In the present study, the annual aboveground NPP was 224.09 $g \cdot m^{-2}$, which is lower than the result obtained by Wang and Li (1994). The difference may be attributed to the different habits of the sampling sites related. On Ordos plateau, the *A. ordosica* community develops best in semi-mobile dunes and the annul biomass production is high, but when semi-mobile dunes turn to fixed dunes, the *A. ordosica* community grows mature and hence the annual NPP drops down (Wang and Li 1994). In the present study, the sampling sites locate at the fixed dunes and the *A. ordosica* community grows mature. Therefore, the NPP is lower than the value estimated by Wang and Li (1994).

As a matter of fact, it is very difficult to precisely estimate biomass and NPP in shrub ecosystems because of the strong patchy vegetation cover. The method of sample plot is often used to measure biomass storage and NPP pattern in terrestrial ecosystems where vegetation distributes uniformly, but this method seems to be inefficient in shrublands. Dong (1996) suggested that harvesting standard size shrub could be a good way to measure biomass storage and NPP in shrub ecosystems. In the present study, we applied the method of standard size shrub and the final results indicate that this method is efficient in shrublands. In addition, according to data we investigated, the biomass storage and NPP were found to be well predicted by shrub volume (cover diameter×height) using power regression. Moreover, Huenneke *et al*. (2001, 2002) also indicated that the shrub volume was a good parameter for estimating biomass and NPP and successfully estimated the NPP patterns in Chihuhuan desert ecosystems in United States. However, the shrub volume used by Huenneke *et al*. was the cover projected surface area multiplying shrub height which presented the shrub volume more precisely. Actually, the precise shrub volume might be more efficient than the parameter of cover diameter×height the present study used. Therefore, measuring the shrub volume more precisely can improve the accuracy of the statistical models. In the easily damaged and sensitive shrub ecosystems, models might be a good way to estimate biomass storage and NPP.

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